SPECIAL METHODS OF SEASONING WOOD

HIGH-TEMPERATURE DRYING: ITS APPLICATION TO THE DRYING OF LUMBER

During World War I, superheated-steam kilns were used in the Pacific Northwest, and very rapid drying rates were reported. Some green, 1-inch softwoods were dried to 10 percent moisture content in 24 hours, at drying temperatures as high as 230° F. in an atmosphere of steam. The relative humidity of the steam was regulated by controlling the dry-bulb temperature and maintaining a wet-bulb temperature at the boiling temperature of water (212° F.). The method is applicable to 1-inch Douglas-fir, true firs, western hemlock, ponderosa pine, southern yellow pine, basswood, and sapwood of sweetgum. So far as is known, it is not suitable for other hardwoods or for softwoods that have a tendency to collapse. The reduction in drying time was well worthwhile, but the severe drying conditions caused such rapid deterioration of materials used in kiln construction that the use of superheated-steam kilns was discontinued in the United States.

While there has been a recent revival of interest in the use of superheated-steam kilns, the principle of drying lumber by this method was recognized as early as 1867, when U. S. Patent No. 64,398, "Apparatus for Drying and Seasoning Lumber by Superheated Steam," was granted to C. F. Allen and Luther W. Campbell, Aurora, Ill. U. S. Patent No. 1,268,180 was granted to H. D. Tiemann, Madison, Wis., June 4, 1918, for a superheated-steam kiln in which circulation was induced by four pairs of steam-spray lines arranged in such a manner that the direction of circulation could be reversed.

Within the past several years, considerable publicity has been given to three German high-temperature kilns. Early forms were constructed of steel or of masonry. Later, a welded construction was developed that consisted of an aluminum lining, about 5 inches of glass wool, and a sheet-steel shell. Such construction is vaportight and provides for a reduction in heat loss and less deterioration of the metal. Ordinarily, such kilns have a capacity of 2,000 to 3,000 board feet of lumber, and they are used primarily in small industrial plants.

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Circulation in these high-temperature kilns is stimulated by disk fans or by centrifugal fans. The disk fan is suitable when the resistance to flow is low, and the centrifugal fan when the resistance is high. The disk fans are reversible. The fan axes may be parallel to or horizontally or vertically perpendicular to the long axis of the kiln (6).[1] The motors are mounted outside the kiln.

Customarily, air-dried softwoods are loaded into a kiln in the morning, the vents and fresh-air intakes are closed, the steam-spray valve is opened unless the evaporated moisture is sufficient to maintain the desired relative humidity, the fans are started, and the heat, either steam or electric, is turned on for several hours, during which the temperature rises to 230° or 239° F. The temperature is maintained for 4 to 10 hours, and then the heat is shut off automatically. In some cases, the vents and the fresh-air intakes are partially opened as soon as the maximum temperature is reached, but ordinarily they are not fully opened until the heat supply is shut off. The wet-bulb temperature may be maintained at 212° F., but it is generally somewhat lower. The fans are in operation during the entire kiln run, which is about 24 hours. Ordinarily, these kilns are not equipped with wet- and dry-bulb recorder-controllers. In some cases, however, the dry-bulb temperature is thermostatically controlled.

Basically, water vapor is superheated when, at any pressure, its temperature exceeds that of the saturated vapor. When the wet-bulb temperature is below 212° F. at atmospheric pressure, both air and water vapor are present. When the wet-bulb temperature reaches 212° F., no air is present. Further heating of the vapor results in superheated steam at atmospheric pressure. In other words, if the wet-bulb temperature in a kiln is below 212° F., the kiln may be called a superheated-vapor kiln. On the other hand, if the wet-bulb temperature is 212° F., and if the dry-bulb temperature is above 212° F., the kiln may be called a superheated-steam kiln. If, however, the dry-bulb temperature is above 212° F., the term "high-temperature" may be applied to the kiln, irrespective of whether the wet-bulb temperature is at or below 212° F.

In order to release heat for evaporation in a kiln at temperatures below the boiling point of water, the temperature of the air and vapor is lowered. The air, of course, can give up heat for evaporation as long as its temperature is higher than that of the wood to be dried. The vapor, on the other hand, can, as its temperature drops, supply heat for evaporation only until the point of saturation is reached. At the standard atmospheric pressure

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[1] Underlined numbers in parentheses refer to references at the end of the report.

of 14.696 pounds per square inch absolute, or zero pound gage, the temperature of saturated steam is 212° F. Wood in contact with such steam could be heated, but the water in it could not be evaporated.

Relative humidity may be defined as the ratio of the actual vapor pressure to the pressure at saturation at the given temperature. For example, at a dry-bulb temperature of 150° F. and a wet-bulb temperature of 132° F., psychrometric curves commonly available to dry-kiln operators show that the dew point is 130° F. and the relative humidity is about 60 percent. In steam tables, which are commonly given in handbooks and textbooks on mechanical engineering, physics, or chemistry, the saturated-vapor pressure at 130° F. is 2.222 pounds per square inch absolute. The corresponding saturated-vapor pressure at 150° F. is 3.718 pounds per square inch absolute. The relative humidity is then $\frac{2.222}{3.718} = 59.8$ percent, which checks with the percentage determined from the curves as described above.

Suppose now, that saturated steam at 14.696 pounds per square inch absolute is superheated from 212° F. to 230° F., while the atmospheric pressure remains unchanged. In other words, the steam is superheated 18° F. Referring again to steam tables, we find that at 212° F. the vapor pressure is 14.696 pounds per square inch absolute, and at 230° F. the vapor pressure is 20.780 pounds per square inch absolute. The relative humidity is then $\frac{14.696}{20.780} = 70.7$ percent.

Most kiln operators are familiar with the relationship of temperature and relative humidity to equilibrium moisture content for temperatures below the boiling point of water at atmospheric pressure. A number of investigators, notably in Germany (5) and in Australia (3), have performed experiments to determine the equilibrium moisture content of wood exposed at atmospheric pressure to superheated steam at temperatures up to 300° F. Eisenmann (2) determined corresponding values for pressures up to 3-1/2 atmospheres, or about 51 pounds per square inch absolute. For temperatures at least up to 248° F. the determinations at atmospheric pressure correspond well with estimations arrived at by the mathematical extrapolation of curves prepared at the U. S. Forest Products Laboratory and dated May 21, 1926.

Kiln Temperatures

Kollman (5) states that drying by superheated steam is suitable for softwoods and beech, but not for green hardwoods, such as oak, which checks and collapses readily. If they are air dried, or kiln dried at a moderate temperature to 25 percent, they can be further kiln dried at a high temperature

without checking In superheated steam at 120° C. (248° F.), the equilibrium moisture content of wood is 4.5 percent, and at 130° C. (266° F.) it is only 3 percent Kollman regards these conditions as too severe and recommends a maximum temperature of 115° C (239° F.) In this case, the equilibrium moisture content is about 5 5 percent. He, as well as Egner (1), considers a range of 110° to 115° C as being most expedient. At 110° C. (230° F) the equilibrium moisture content is 7 percent.

Rates of Circulation

Various investigators advocate rates of circulation of from 2 to 10 meters per second (394 to 1,970 feet per minute); 2 to 3 meters per second (394 to 590 feet per minute) are most commonly mentioned. Among the factors affecting the rates are, presumably, differences in species, in initial moisture content, in temperature, in relative humidity, and in length of air travel. Because high temperatures result in high rates of drying, it is to be expected that the rates of circulation mentioned for foreign kilns would be higher than those used in American kilns, in order to carry the moisture away from the lumber as rapidly as it comes to the surface.

Energy Required for Drying

Keylwerth (4) indicates that, with a superheated-vapor kiln, the usual range of energy required is 1.2 to 1.5 kilowatt-hours per kilogram (2.2 pounds) of water evaporated and that the corresponding range is 2 to 4 kilowatt-hours with low-temperature drying. He attributes the lower energy requirement to the lower heat loss, lower heat capacity of the construction materials, and the shorter drying time in the superheated-vapor kiln

Effects of High-Temperature Drying on Wood Properties

Keylwerth (4) found that samples of red beech dried in superheated steam at 115° C. (239° F.), as compared with those dried at 65° C (149° F.), had an equilibrium moisture content value about 2 percent lower at 12 percent moisture content, also, they had somewhat higher modulus of rupture, maximum crushing strength, and modulus of elasticity In impact bending and in

tension perpendicular to the grain, however, the samples dried at 115° C. had somewhat lower values. The radial and tangential shrinkages were reduced 24 and 20 percent, respectively. Graf and Egner reported, according to Eisenmann (2), that pine dried at 115° C. (239° F.) shrank and swelled only 70 percent as much as air-dry pine.

According to Kollman (5) the discoloration (presumably chemical brown stain) in pine was very slight when the green lumber was dried at temperatures up to 70° C. (158° F.).

Available information concerning the effect of high-temperature drying on casehardening is not very detailed. General reports indicate, however, that casehardening resulting from this method of drying is not of commercial importance in Germany.

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